Field Measurements of Sediment Transport Processes in STRATAFORM: Extended Duration Observations

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LONG-TERM GOAL

The long-term goal of the sediment dynamics component of STRATAFORM is to link sediment transport processes on the continental shelf and slope to the formation and preservation of event beds in sediment deposits.

OBJECTIVES

Our objective is to investigate sediment dispersal mechanisms on the continental shelf and slope. We maintained long-term monitoring instrumentation as part of the STRATAFORM project in support of these investigations. In particular, we have focussed on analysis of the data to address the following specific topics in the past fiscal year:

- temporal variability (intra- and inter-annual) of sediment flux on the continental shelf and slope,
- delivery of suspended sediment to the continental slope and the formation of bottom and intermediate nepheloid layers,
- role of canyons on suspended sediment transport in the shelf/slope system, and subsequently on the sediment budget, and
- seabed roughness as a function of biological and physical reworking.

APPROACH

A shelf tripod in 60 m water depth (S60) and a slope mooring in 450 m (Y450) were deployed for five years (September 1995 to April 2000) and collected data to address questions of shelf and slope sediment transport processes. Additionally, instrumentation was placed in the head of Eel Canyon, in the winter of 1999/2000 providing an opportunity to investigate canyon processes. These measurements of near-bed currents, water properties, suspended sediment concentration and suspended sediment properties, and bottom-looking video have been supplemented by water column profiling and seabed coring. The long time-series data set is valuable for: analysis of inter-annual and seasonal transport patterns, establishing the dynamics of resuspension and transport over a variety of storm and flood conditions, evaluation of river discharge effects on transport mechanisms, and validation of circulation and sediment transport models. Extended duration observations at S60 have also supported

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The long-term goal of the sediment dynamics component of STRATAFORM is to link sediment transport processes on the continental shelf and slope to the formation and preservation of event beds in sediment deposits

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the plume/inner shelf studies. This includes observations to track the increases of nearbed suspended sediment, and net flow directions of nearbed fluid mud layers during storm and flood events, as well as, the correlation of the mud layers to strata development.

The current and suspended sediment data from the Y450 subsurface slope mooring supplemented by CTD-Transmissometer profile data enables evaluation of the magnitude and mechanisms of particulate transport to the slope, and transport off the slope in the form of bottom and intermediate nepheloid layers. The winter canyon data set (both bottom boundary layer and water column) provides the ability to investigate processes active in the canyon, and to estimate of the contribution of the canyon to off-shelf transport and to the sediment budget.

WORK COMPLETED

Data analysis of the near continuous time-series of current, wave, and suspended sediment concentration data at the shelf and slope locations was continued in this fiscal year. The winter data set in the head of the Eel Canyon has been analyzed to evaluate the role of the canyon in the Eel sediment dispersal system and has provided new results on canyon processes. In this past year, publications have been prepared and are close to submission.

RESULTS

Sediment transport processes have been studied on the continental shelf in a variety of environments. The role of waves and wave-current interaction on sediment resuspension and transport has been investigated. The limitation of these past observational studies has been the duration of time in which the processes have been observed. The long-term monitoring component of the STRATAFORM project provided a framework in which five years of bottom boundary layer processes could be obtained, and the variability of processes over longer time periods could be investigated. Additionally, extreme events have a higher probability of being observed as the length of time-series is expanded. It has been observed that the extreme events can either erase or build the stratigraphic record.

The results from the five years of current, wave, and suspended-sediment data show significant temporal variability, both inter-annual and intra-annual, of sediment flux on the northern California continental shelf. Both the river discharge hydrograph and the atmospheric forcing varies inter-annually, and the last five years of data obtained includes an 80-year flood, and both El Nino and La Nina forcing. In the across-shelf direction, the flux is directed seaward during all five winters, whereas, in the along-shelf direction the flux direction differs between winters, with the resulting net transport over the five years approaching zero.

Variability in the sediment flux, both temporally and spatially, may be attributed to complex circulation on the shelf and slope in the study area. One of the objectives of the analyses is to examine the net sediment flux on the mid-shelf mud deposit, looking at the variability between different years and putting the low-frequency (interannual) variations in context of the physical forcing on the shelf. The changes observed with ENSO cycles have big implications for the long-term (50-100 year scale) sediment fluxes, and thus the amount of sediment that is captured within the mid-shelf deposit. The fluctuating component of flux in the alongshelf direction accounts for over two thirds of the net alongshelf flux with the tidal and wind bands being the major contributors. Since the fluctuating flux component is large, if not the dominant part of the total signal, significant errors can result if shelf sediment flux is estimated on the basis of mean flux calculations (i.e., mean concentration times mean

velocity) alone. This analysis emphasizes the point that while gravity waves are known to be the major sediment suspension mechanism on continental shelves, lower-frequency motions ranging from tides to meso-scale circulation have a major impact on shelf sediment transport. Interactions with physical oceanographic modelers using nested circulation models in the study area have shown that large-scale circulation at the instrumentation sites can be quite variable and is affected by flow separation around Cape Mendocino during wind reversals associated with typical winter storm systems on this coastline.

Of the sediment that is resuspended on the shelf, little can be directly related to suspended sediment observed on the slope. At the upper-slope mooring site (Y450), the horizontal flux of sediment is less responsive to suspension by wave-current interaction and advection from the river plume than on the shelf. At times, suspended sediment does appear to be advected from the shelf at the shelf-break depth to the slope, and at other times a correlation is not observed. On the open slope, CTD-Transmissometer surveys show the geographic and seasonal distribution of intermediate nepheloid layers (INL). INLs could be classified as either shelf INLs, generated between 60 and 200 m depth, or slope INLs which detached from the continental slope at depths greater than 200 meters. Both shelf and slope INLs were often associated with regions of critical topography. Shelf INLs were strongest in winter, suggesting that their generation is associated with the supply of sediment from shelf wave resuspension. Internal wave reflection (which occurred in intermittent pulses on this slope) may be responsible for the generation of slope INLs. Temporal variation in internal wave energy may explain the distribution of suspended sediment observed on the slope and the poor correlation with the shelf regime.

In the Eel Canyon, correlations between high-energy events on the shelf and suspension events indicate that the canyon may be a sink under certain environmental conditions. Results from the canyon instrument deployments have identified the presence of storm-induced density-driven flows occurring at the head of the Eel submarine canyon. Increases of the near-bottom suspended-sediment concentrations (SSC) at the head of the canyon were not directly related to the Eel River discharge, but they were linked to the occurrence of storms. Bottom boundary layer (BBL) measurements at 120-m depth in the canyon axis revealed that during intensification of the wave-orbital velocity, sediment transport at the head of the canyon takes place as density-driven currents flowing down-canyon. At higher sampling frequencies (1 Hz), the current components during these events fluctuate at the same periodicity as the pressure, reflecting a clear influence of the surface wave activity on the generation and maintenance of the density driven flows. On the shelf, increases of SSC during storms correlated with observations in the canyon. However, SSC at the S-60 site was usually not high enough to provide sufficient density anomaly to generate density-driven currents. Only during a highly energetic storm ($H_s \sim 9$ m), the SSC on the shelf at 13 cm above the bottom (cmab) reached values in excess of 10 g l-1. During that storm event, at 280-m depth in the canyon, the near-bottom (15 mab) SSC reached 103 mg l-1, whereas in mid-waters (115 mab), SSC increased 3 hours later and reached maximum values ~30 mg l-1. This combined data set shows that storms can be a mechanism to induce density-driven currents, particularly at the head of submarine canyons, and reveals that this kind of sediment transport process can be more frequent that previously expected. Liquefaction of surface sediments induced by surface waves due to excess pore-water pressures combined with elevated slopes the canyon head may help to initiate sediment transport.

IMPACT/APPLICATION

The data analysis phase of the STRATAFORM project has emphasized the interannual variability that occurs on the shelf, and thus the relevance of long-term data sets for evaluation of sediment transport processes and the ultimate fate of river-discharged sediment particles. The canyon study has also revealed the potential importance of canyons in the sediment dispersal system in modern (high-stand) times, and the likely potential for frequent downslope gravity flows that impact the sediment budget of the shelf/slope system.

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